

## **8.15            Geologic Resources and Hazards**

GWF Energy LLC proposes to build and operate the Tracy Peaker Project (TPP), a nominal 169-megawatt (MW) simple-cycle power plant, on a nine-acre, fenced site within a 40-acre parcel in an unincorporated portion of San Joaquin County. The site is located immediately southwest of Tracy, California, and approximately 20 miles southwest of Stockton, California. The TPP would consist of the power plant, an onsite 230-kilovolt (kV) switchyard, an approximately five-mile, 230-kV electric transmission line, an approximately 1,470-foot water supply pipeline (as measured from the fence line), an onsite natural gas supply interconnection, and improvements to an existing dirt access road approximately one mile in length. An approximately 5.2-acre area west of the plant fence line and within the 40-acre parcel would be used for construction laydown and parking. Figure 2-1 shows the regional location of the GWF site. Figure 2-2 shows the immediate site location of the GWF project, including the location of the proposed generating facility and the proposed transmission, water supply, and access routes. The site is near the western edge of the San Joaquin Valley within the Great Valley Geomorphic province, astride the boundary between the Great Valley to the east and the Coast Ranges to the west (locally the Diablo Range). The proposed new and existing transmission lines would run across the foothills of the Diablo Range.

The primary points of geologic interest in the project area are the seismic activity, and the presence of expansive soils in the subsurface of the proposed site and transmission line corridor. Strong earthquake shaking was felt at the site in 1906 and 1989 during the San Francisco and Loma Prieta earthquakes. Maximum intensities were Modified Mercalli (MM) VI. Borings at the proposed site indicate the presence of expansive soils in the top 5 feet. Surficial soil maps of the proposed transmission line corridor indicate that soils have a high shrink-swell potential.

### **8.15.1            Affected Environment**

#### **8.15.1.1           Regional Geology and Physiography**

The proposed site is located along the boundary between the Coast Ranges and the Great Valley (Central Valley) physiographic provinces (Figure 8.15-1). This region is known as

the Coast Ranges–Sierran Block boundary zone (CRSBBZ) and is delineated by a series of low hills and complex thrust/reverse faulting (see Section 8.15.1.2). The Great Valley and the adjacent Sierra Nevada form a relatively stable crustal block (Sierran block) composed of Mesozoic crystalline basement that dips gently to the west (Hill et al., 1991). The western edge of the Sierra Nevada block, beneath the sediments of the Great Valley, is generally thought to be coincident with the western margin of the Great Valley.

The Great Valley physiographic province separates the Coast Ranges to the west from the Sierra Nevada in the east (Figure 8.15-1). This province is comprised of two elongated northwest- to southeast-trending basins: the Sacramento basin to the northwest and the San Joaquin basin to the southeast. This province is approximately 435 miles (700 kilometers) long and 44 to 56 miles (70 to 90 km) wide, and characterized by a thick, relatively undeformed sequence of alluvium and volcanic deposits. The present-day basin evolved from a late Jurassic to middle Tertiary (40–150 million years [Ma]) marine fore-arc basin (Dickinson, 1981; Castillo and Zoback, 1994). In the late Tertiary (25–30 Ma), a change in the relative motion between the Pacific and North American plates resulted in the gradual uplift of the Coast Ranges and the eventual isolation of the basin from the ocean. More recent Miocene and lower Pliocene sediments were derived from the neighboring Coast Ranges and the Sierra Nevada (Perkins, 1987). By the late Pliocene (2–3 Ma), subaerial depositional conditions prevailed and Sierra Nevada–derived sediments were deposited in the basins (Bartow, 1987).

The Coast Ranges are a north-northwest- to northwest-trending series of mountains and intervening valleys extending for 597 miles (960 km) from the Oregon border, south to the Santa Ynez River near Santa Barbara. Physiographically, the Coast Ranges can be divided into two subprovinces, the northern and southern subprovinces, separated by the San Francisco Bay and the Sacramento River Delta. The Coast Ranges are underlain by uplifted and intensely deformed Upper Jurassic (150 Ma) and younger rocks of the Franciscan ophiolite complex and the Salinian metamorphic and granitic complex.

### 8.15.1.2 Regional Seismotectonic Setting and Seismicity

The project site is located in central California and within the CRSBBZ (see Figures 8.15-1 and 8.15-2). The modern tectonic setting of central California is dominated largely by the transform plate boundary contact between the Pacific and North American plates south of the Mendocino triple junction. The Pacific plate is slipping in a north-northwest direction (N35°W to N38°W) at a rate of about 1.81 to 1.95 inches per year (46 to 47 millimeters per year) with respect to the North American plate (DeMets et al., 1994). Right-lateral strike-slip displacement along the major branches of the San Andreas fault system accommodates most of this plate motion, with the remainder generating Holocene tectonism and seismicity at the western continental margin and to the east in the Sierra Nevada and Basin and Range Provinces (Minster and Jordan, 1987; Atwater, 1970). East of the Coast Ranges, in the CRSBBZ, compressional deformation occurs on reactivated east-verging, low-angle structures (Unruh and Moores, 1992; Unruh and Lettis, 1998). High slip-rate faults associated with the San Andreas fault system lie to the west of this boundary zone.

**Significant Faults.** The western margin of the San Joaquin Valley in the vicinity of the project site is characterized by a few active and potentially active faults. There are numerous Quaternary faults within a 62-mile (100-km) radius of the site, some of which have generated large, damaging earthquakes during historic time (see section on Historical Seismicity, below) (Figure 8.15-2). Most of these sources are faults within the San Andreas fault system, including the San Andreas, San Gregorio, Hayward–Rodgers Creek, Calaveras, and Concord–Green Valley faults. This section also considers faults within the CRSBBZ. The most significant faults are listed in Table 8.15-1, along with estimates of the maximum magnitude for each fault.

Maximum magnitude estimates are based, for the most part, on the Working Group on Northern California Earthquake Potential (WGNCEP) (1996), Working Group on California Earthquake Probabilities (WGCEP) (1999), and empirical relationships between fault rupture length, fault rupture area, and maximum magnitude (Wells and Coppersmith, 1994). The most significant Quaternary faults within a 62-mile (100 km) radius of the site are discussed briefly below.

**Coast Range-Sierra Block Boundary Zone (CRSBBZ).** The CRSBBZ was the probable source of the 1892 moment magnitude (M) 6.4 and 6.2 Vacaville-Winters earthquakes and the 1983 M 6.5 Coalinga earthquake (Wong and Ely, 1983; Wong et al., 1988; Unruh and Moores, 1992; Wakabayashi and Smith, 1994; Bakun, 1999; O'Connell et al., 2001). The CRSBBZ is a complex zone of thrust faulting that marks the boundary between the Coast Ranges block and the Sierran basement rocks that are concealed beneath the Great Valley sedimentary rocks of the Sacramento and San Joaquin Valleys (Figure 8.15-2). The basal detachment within the CRSBBZ is a low-angle, west-dipping thrust accommodating eastward thrusting of the Coast Ranges block over the Sierran block. Above this detachment is a complex array of west-dipping thrusts and east-dipping back-thrusts. These constitute fault-propagation folds that form a series of low hills that extend for over 311 miles (500 km), from near Red Bluff in the northern Sacramento Valley to Wheeler Ridge in the southern San Joaquin Valley (Wakabayashi and Smith, 1994; Wong et al., 1988). Although the faults themselves do not rupture to the surface, the CRSBBZ is marked along much of its length by an alignment of fault-propagation folds such as the Rumsey Hills. This relatively linear alignment is interrupted by the Sacramento River Delta, where the CRSBBZ takes a right-step between the Montezuma Hills to the north and the Los Medanos Hills to the south (Wakabayashi and Smith, 1994). This complexity is most likely the result of the interaction of right-lateral strike-slip faulting and left-stepping restraining bends on faults that belong to the San Andreas fault system (Unruh et al., 1997; Wakabayashi and Smith, 1994).

Mapping of Quaternary deposits, geomorphic analysis of Quaternary fluvial landforms, and analysis of faults and bedrock structures by Sowers et al. (1992) suggest that Quaternary surfaces may be tectonically deformed and that active crustal shortening is taking place along the Diablo Range front from Tracy to Patterson just west of the site.

The overall pattern of faulting, folding, and uplift is consistent with the CRSBBZ model of blind-thrust faulting of a tectonic wedge northeastward beneath the margin of the range, and high-angle faulting (e.g., Black Butte fault) beneath the mountain front. The faults and folds are interpreted as secondary structures developed during regional uplift and tilting (Sowers et al., 1992).

Based on differences in geomorphic expression and fault geometry, Wakabayashi and Smith (1994) divided the CRSBBZ into a number of segments. The WGNCEP (1996) has since modified this segmentation model, using the rupture geometry of the 1983 Coalinga earthquake as a “characteristic” event. Recent investigations by Unruh and Hector (1999) and O’Connell et al. (2001) have further refined the segmentation of the CRSBBZ in the region north of and surrounding the Delta. These faults are discussed in more detail in the following sections. Fault activity is expressed in terms of slip rate, as determined by Wakabayashi and Smith (1994) and refined by WGNCEP (1996). The preferred geologic slip rate estimate for the whole zone is 0.059 in/yr (1.5 mm/yr), with an error of  $\pm 0.020$  in/yr ( $\pm 0.5$  mm/yr). The Tracy segment of the CRSBBZ, which is the closest segment to the site (approximately 1 km, see Figure 8.15-2), is capable of generating a maximum earthquake of M 6.7 (WGNCEP, 1996) (Table 8.15-1).

**Sacramento Delta Faults.** Recent investigations in the Delta region have revealed a number of Quaternary active thrust faults beneath a series of right-stepping en echelon anticlines to the north of Mount Diablo (Unruh and Hector, 1999; Weber-Band, 1998). These faults include the Roe Island thrust, Potrero Hills thrust fault, Pittsburg–Kirby Hills fault, and the Midland fault (Figure 8.15-2).

Previous models for seismic sources in the Delta region have assumed a through-going buried or blind-thrust fault representing the local continuation of the CRSBBZ through the central part of the Delta. The lack of Coalinga-type anticlines through the Delta region indicates that blind thrusts of the CRSBBZ, if present, must have a lower slip rate than the “type” structures of the CRSBBZ to the south. Unruh and Lettis (1998) proposed an alternative kinematic model for the deformation in this region that does not involve a through-going CRSBBZ thrust structure; instead, they have a series of smaller, less active thrust faults.

The Roe Island thrust underlies the asymmetric Roe Island anticline in Suisun Bay. This fold and the underlying thrust fault are well documented from gas exploration wells and seismic reflection data (Unruh and Hector, 1999). The northeast-dipping thrust fault is considered capable of generating a M 5.5 to 6.0 (Unruh and Hector, 1999). Slip-rate estimates

range from 0.011 to 0.028 in/yr (0.3 to 0.7 mm/yr), with a preferred value of 0.020 in/yr (0.5 mm/yr).

The Potrero Hills thrust fault underlies the north-tilted Potrero Hills anticline, located just south of Fairfield. Unruh and Hector (1999) consider this fault capable of generating a maximum earthquake of M 6. Estimates of fault slip-rate range from 0.004 to 0.024 in/yr (0.1 to 0.6 mm/yr), with 0.012 in/yr (0.3 mm/yr) representing the best estimate for the long-term slip rate.

The Pittsburg–Kirby Hills fault (PKHF) (previously known as the Vaca–Montezuma Hills fault) is a right-lateral tear fault that bounds the eastern margin of a series of folds and thrusts in the Grizzly Bay–Van Sickle Island area (Unruh et al. 1997). The PKHF is highlighted by a linear alignment of microseismicity, which is unusual in that it occurs at depths of 12 to 16 miles (20 to 25 km) (Wong et al., 1988). Focal mechanisms indicate that the movement on the fault is almost pure right-lateral strike-slip. The 1889 Richter magnitude ( $M_L$ ) 6.0 Antioch earthquake may possibly have occurred on the PKHF (Unruh and Lettis, 1998), most likely the same feature as the Antioch fault referred to in Wong et al. (1988) and Jennings (1994). Unruh and Hector (1999) assign a maximum earthquake of M 6.3 to the PKHF. Estimates for the slip rate of the PKHF range from 0.011 to 0.028 in/yr (0.3 to 0.7 mm/yr).

The Midland fault is a west-dipping fault located along the eastern margin of the Montezuma Hills. This fault accommodated subsidence of the Sacramento basin during early Tertiary time. From detailed analysis of seismic reflection data, late Cenozoic reactivation of the Midland fault to accommodate reverse-slip and horizontal crustal shortening has been documented (Weber-Band, 1998). This reverse reactivation of the Midland fault has resulted in uplift of the eastern Montezuma Hills. From the offset of known Cenozoic reflectors, the Midland fault is estimated to have a slip rate of 0.004 to 0.024 in/yr (0.1 to 0.6 mm/yr), but the preferred estimate is 0.006 in/yr (0.15 mm/yr) (Unruh, William Lettis and Associates, Inc., 1999). The maximum earthquake for the Midland fault is considered to be  $M 6.3 \pm 0.3$ .

**Greenville Fault.** This fault is a north-northwest- to northwest-striking strike-slip fault of the San Andreas system in the northern Diablo Range (Figure 8.15-2). The

Greenville fault generally is assumed to continue north of Livermore Valley as the Marsh Creek–Clayton system; however, the well-defined surface trace of the fault dies out or diminishes markedly several miles north of Livermore Valley, and the Marsh Creek–Clayton fault system is considerably less active than the northern Greenville fault east of Livermore. Evidence for right-lateral displacement on the Greenville fault includes right-laterally offset drainages and sidehill benches, and right-lateral surface offsets observed along traces of the fault following the January 1980  $M_L$  5.8 Livermore earthquake sequence (Hart, 1981). Available data on the late Quaternary slip rate of the Greenville fault are sparse and have significant uncertainties. The WGCEP (1999) assigned a maximum earthquake of  $M$  7.2 and a minimum slip rate of 0.079 in/yr (2 mm/yr) to the Greenville fault. The recurrence interval is estimated to be on the order of 550 years. The project site is located approximately 9 miles (15 km) to the east of the Greenville fault (Table 8.15-1 and Figure 8.15-2).

**Concord-Green Valley Fault.** The Concord fault (Figure 8.15-2), and its continuation on the northern side of San Francisco Bay, the Green Valley fault, is a northwest-striking right-lateral strike-slip fault of the San Andreas system. The Concord fault extends for 11.2 miles (18 km) along the eastern margin of Ygnacio Valley, from the northern slopes of Mount Diablo to Suisun Bay. North of the Bay, the Green Valley fault extends northwards for a distance of approximately 25.7 miles (43 km). The northern end of the Green Valley fault is defined by a change in fault strike and a gap in microseismicity (WGCEP, 1999). The WGCEP (1999) also included the Cordelia fault within the Concord–Green Valley fault system.

The WGCEP (1999) has assigned a slip rate of  $0.157 \pm 0.079$  in/yr ( $4 \pm 2$  mm/yr) for the Concord and  $0.197 \pm 0.079$  in/yr ( $5 \pm 2$  mm/yr) for the Green Valley fault. Based on differences in geomorphic expression, fault geometry, paleoseismic chronology, slip rate, and seismicity, the Concord–Green Valley fault is divided into three fault segments: the Concord fault, the southern Green Valley, and northern Green Valley faults. The WGCEP (1999) assigned a maximum earthquake of  $M$  6.8 that ruptures the entire length of the Concord–Green Valley fault system (Table 8.15-1).

**Mount Diablo Thrust Fault.** This thrust fault is a northeast-dipping, southwest-propagating thrust fault beneath the Mount Diablo anticline (Figure 8.15-2). Unruh and Sawyer

(1995) proposed that slip on the northern Greenville fault appears to die out northward, because the fault steps to the northwest across Mount Diablo to join with the right-lateral Concord fault. This model argues that the Mount Diablo anticline is a contractional left-stepover between the Greenville and Concord faults. Unruh and Sawyer (1995) specifically proposed that Mount Diablo is an asymmetric, southwest-vergent fault-propagation fold underlain by a northeast-dipping blind-thrust fault that links the northern Greenville fault to the Concord fault.

Long-term average Quaternary shortening rates across the Mount Diablo region, estimated from construction of balanced cross sections, are  $0.134 \pm 0.035$  in/yr ( $3.4 \pm 0.9$  mm/yr) (Unruh and Sawyer, 1997). Considering the likely fault geometry, an average slip rate for the Mount Diablo thrust would be approximately  $0.151 \pm 0.055$  in/yr ( $4.1 \pm 1.4$  mm/yr), and it is probably capable of generating a maximum earthquake of M 6.75. Based on an average coseismic slip during the maximum event and the calculated slip rate, Unruh and Sawyer (1997) proposed an average recurrence of approximately 230 to 740 years for the Mount Diablo thrust.

**Calaveras Fault.** This fault is a main component of the San Andreas system, branching off the main San Andreas fault south of Hollister, and extending northwards for approximately 75 miles (120 km) (Figure 8.15-2). The closest approach of the Calaveras fault to the site is about 22 miles (35 km) (Table 8.15-1). The predominant sense of motion on the Calaveras fault is right-lateral strike-slip. A smaller component of vertical displacement is evident in some areas along the fault trace. The Calaveras fault has generated a number of moderate-size earthquakes in historic time. The long-term slip rate and contemporary creep rate for the southern Calaveras fault are approximately  $0.59 \pm 0.118$  in/yr ( $15 \pm 3$  mm/yr), while the northern Calaveras fault has a creep rate of approximately 0.236 in/yr (6 mm/yr) (WGCEP, 1999). The WGCEP (1999) suggests a recurrence interval of approximately 360 years for a maximum earthquake of M 7.0 on the northern Calaveras fault. The recurrence interval for a maximum event of M 7.2 on the entire length of the Calaveras fault is approximately 1,733 years (Table 8.15-1).

**Hayward-Rodgers Creek Fault System.** The Hayward fault extends for 62 miles (100 km) from the area of Mount Misery, east of San Jose, to Point Pinole on San Pablo Bay (Figure 8.15-2). The northern continuation of this fault system is the Rodgers Creek fault.

The two faults are separated by a 3.1-mile-wide (5-km-wide) right-step beneath San Pablo Bay. The last major earthquake on the Hayward fault, in October 1868, occurred along the southern segment of the fault. This M 6.8 event caused toppling of buildings in Hayward and other localities within about 3.1 miles (5 km) of the fault. The WGCEP (1999) considers the Hayward–Rodgers Creek fault system the most likely source of the next M 6.7 or larger earthquake in the Bay Area, with a 32 percent probability in the time period 2000 to 2030. Rupture of the Hayward fault would generate a maximum earthquake of M 7.1.

The Rodgers Creek fault is 27.3 miles (44 km) long and has a similar geomorphic expression to the Hayward. Holocene activity along the Rodgers Creek is indicated by a series of fault scarps in Holocene deposits, side-hill benches, right-laterally offset streams, and closed linear depressions. Paleoseismic investigations by Schwartz et al. (1992) revealed three events in 925 to 1,000 years. This gives a preferred recurrence of 230 years for a maximum earthquake of M 7.1. Rupture of the entire length of the Hayward–Rodgers Creek fault system would generate a maximum earthquake of M 7.4 (Table 8.15-1).

**Ortogonal Fault.** This fault is a 41-mile-long (66-km-long), north-northwest-striking, right-lateral strike-slip fault located in the southern Diablo Range (Figure 8.15-2). The fault extends from Panoche to southeast of Mount Stakes. The fault consists of two distinct geometric segments, separated by a 3.1-mile-wide (5-km-wide) right-step across San Luis Reservoir. Much of the fault is delineated by persistent microseismicity. The fault is marked by geomorphic indicators of recent strike-slip faulting, including deflected drainages, shutter ridges, sidehill benches, and vegetation lineaments (Anderson et al., 1982). Paleoseismic trenching investigations have estimated a slip rate of  $0.039 \pm 0.020$  in/yr ( $1.0 \pm 0.5$  mm/yr). The maximum earthquake for the Ortogonal fault is M 6.9, with an effective recurrence of 1,100 years (WGNCEP, 1996).

**San Andreas Fault System.** The dominant fault structure in the coastal California region is the San Andreas fault system. The San Andreas fault extends from the Gulf of California, Mexico, to Point Delgada on the Mendocino Coast in Northern California, a total distance of 746 miles (1,200 km) (Figure 8.15-2). The San Andreas fault accommodates the majority of the motion between the Pacific and North American plates. This fault is the longest

active fault in California and is responsible for the largest known earthquake in Northern California, the 1906 M 7.9 San Francisco earthquake (Wallace, 1990). Movement on the San Andreas fault is right-lateral strike-slip, with a total offset of some 348 miles (560 km) (Irwin, 1990). In Northern California, the San Andreas fault is clearly delineated, striking northwest, approximately parallel to the vector of plate motion between the Pacific and North American plates. Over most of its length, the San Andreas fault is a relatively simple, linear fault trace. Immediately south of the Bay, however, the fault splits into a number of branch faults or splays, including the Calaveras and Hayward faults.

Based on differences in geomorphic expression, fault geometry, paleoseismic chronology, slip rate, seismicity, and historic fault ruptures, the San Andreas fault is divided into a number of fault segments. Each of these segments is capable of rupturing either independently or in conjunction with adjacent segments. In the Bay Area, these segments include the Santa Cruz Mountains segment; the Peninsula segment, which is the closest segment to the site (45 miles [74 km] away); and the North Coast segment. The WGCEP (1999) assigns a recurrence interval of 361 years to a M 7.9 1906-type event on the San Andreas fault, with a 21 percent probability of a M 6.7 or larger earthquake on the San Andreas in Northern California in the time period 2000 to 2030. They assign a maximum earthquake of M 7.2 to the Peninsula segment (WGCEP, 1999) (Table 8.15-1).

**San Gregorio Fault Zone.** This northwest-striking fault is the principal active fault west of the San Andreas fault in the coastal region of central California. The fault extends from just offshore of Point Sur, northward to Bolinas Lagoon, where it merges with the North Coast segment of the San Andreas (Figure 8.15-2). The majority of the fault is located offshore, with only two short sections, at Seal Cove and Moss Beach, occurring on land. Because of the limited onshore extent of the fault, the fault is relatively poorly understood. Jennings (1994) shows the fault as two distinct segments, separated by a prominent step in Monterey Bay. Simpson et al. (1997) carried out one of the few paleoseismic investigations along the fault, which demonstrated late Holocene right-lateral movement on the Seal Cove section of the fault. The most recent surface-faulting event occurred sometime after A.D. 1270 to 1400, but prior to 1775. A penultimate event occurred between A.D. 680 and 1400 (Simpson et al., 1997). Estimates of slip along the San Gregorio fault are highly variable. Simpson et al. (1997) give a

range of 0.157 to 0.394 in/yr (4 to 10 mm/yr), while the WGCEP (1999) assigned a slip rate of  $7 \pm 3$  mm/yr to the northern San Gregorio fault and  $0.118 \pm 0.079$  in/yr ( $3 \pm 2$  mm/yr) to the southern part of the fault.

Based on the geological and paleoseismic data presented above, the San Gregorio fault is divided into two segments: a northern segment extending from Bolinas Lagoon to Monterey Bay and a southern segment from Monterey Bay to just north of Point Sur. The northern segment of the San Gregorio fault is located 60 miles (96 km) west of the project site at its closest approach. The WGCEP (1999) assigned a maximum earthquake of M 7.5 for an event rupturing the entire length of the San Gregorio fault.

**Other Faults.** Other faults in the vicinity of the project site include: the Rio Vista, Midway, Vernalis, Black Butte, and San Joaquin faults (Figure 8.15-2), all of which are identified by Jennings (1994) on his fault map of California. However, these faults are not considered to be significant seismic sources in our analysis due to their individual short lengths, uncertainty in exact location, and/or lack of proven late-Quaternary activity.

**Historical Seismicity.** The historical earthquake record for the Sacramento and San Joaquin Valleys only extends back to the mid-1800s, coinciding with the influx of miners and settlers during the Gold Rush (Toppozada et al., 1981; Wong, 1992). Until adequate seismographic coverage came into existence in central California in the 1930s, earthquake detection was generally limited to those events that produced felt or physical effects. Earthquakes as small as  $M_L$  3.0 were probably not completely observed throughout the San Joaquin Valley until about 1960. Thereafter, seismographic coverage in California improved significantly, and currently earthquakes as low as  $M_L$  2.0 to 2.5 can be detected for most portions of the San Joaquin Valley.

The site is located within the CRSBBZ, and in a region that historically has been seismically active (Figure 8.15-3). The largest historical earthquakes have generally occurred along the major faults associated with the San Andreas fault system, in addition to three events within the CRSBBZ (e.g., 1892 Vacaville-Winters earthquakes). An area of particular seismic quiescence is in the valley around and south of Sacramento.

A historical catalog from 1852 to 2000 was compiled for the study region; the epicentral locations are shown on Figure 8.15-3. The study region encompasses an area approximately 62 miles (100 km) in radius from the site and includes all seismic sources that may generate potential strong ground shaking. The catalog was compiled from the following data sources: the National Earthquake Information Center's Preliminary Determination of Epicenters; Stover, Reagor, and Algermission's U.S. historical catalog; the catalog of the California Division of Mines and Geology, 1735–1974; the catalog of the University of California at Berkeley; and the Northern California Seismic Network catalog. The resulting catalog (1808–2001) for the site region consists of nearly 3,152 earthquakes of approximate  $M_L$  3.0 and greater (Figure 8.15-3).

**Significant Earthquakes.** Eighteen earthquakes of estimated  $M_L$  6.0 or greater have occurred within 62 miles (100 km) of the project site in historical times. Earthquakes of this magnitude pose significant ground-shaking hazard to the project site. Some of these events are annotated on Figures 8.15-1 and 8.15-3, and the significant earthquakes are discussed in more detail below. The closest earthquake to the site (approximately 0.87 miles [1.4 km]) occurred on July 13, 1946, and measured a  $M_L$  3.4 in size.

- **June 21, 1808:** This earthquake caused severe damage to a number of adobe buildings at the Presidio of San Francisco (Figure 8.15-3) was followed by a number of aftershocks through July 17 and 18 and had a maximum intensity of Modified Mercalli (MM) VIII. Toppozada et al. (1981) estimated that this event occurred in the area of the Golden Gate, possibly on the San Andreas fault, and was  $M_L$  6.0 in size.
- **June 10, 1836:** For several decades, this earthquake was thought to be associated with the Hayward fault, as is the 1868  $M_L$  6.8 earthquake. Lindh (1983) proposed that the 1836 earthquake probably ruptured the northern Hayward fault, while the 1868 earthquake was probably centered on the southern Hayward fault. This explains the occurrence of two large earthquakes on the same fault in only 32 years. However, Toppozada and Borchardt (1998) re-evaluated historical evidence and concluded that this earthquake was erroneously associated with the Hayward fault, and most likely occurred on the San Andreas fault somewhere between Monterey and Santa Clara. Toppozada and Borchardt (1998) assigned this event a  $M_L$   $6.25 \pm 0.5$ , based on felt reports. Recent trenching studies on the northern Hayward fault found little evidence for movement in the 1800s and corroborate this interpretation.
- **June 1838:** Very few written records of the June 1838  $M_L$  7.5 earthquake exist, and the exact date is not known (Figure 8.15-3). No reports of this

earthquake are available from north of San Francisco or south of Santa Clara, except from Monterey (Topozada et al., 1981). Topozada and Borchardt (1998) reviewed the historical records and found that reported shaking intensities suggest this earthquake was the result of a larger rupture than the 37.3-mile- (60-km-) long Peninsula segment of the San Andreas fault. Rupture may have extended a distance of 87 miles (140 km), from San Francisco to San Juan Bautista.

- **November 26, 1858:** A  $M_L$  6.1 with a reported maximum intensity of MM VII destroyed a number of adobe buildings in San Jose and caused structural damage in Mountain View and San Francisco (Topozada et al., 1981) (Figure 8.15-3). The distribution of isoseismals (contours of equal shaking intensity) indicates that this event was centered in the southeastern part of the Bay Area, either on the southeast extension of the Hayward fault, or on the central section of the Calaveras fault.
- **October 21, 1868:** This  $M_L$  6.8 earthquake occurred on the southern Hayward fault (Figure 8.15-3). It was one of the most destructive in historical times because it occurred in a populated area. Heavy damage was sustained in towns in the eastern Bay Area, as well as in San Francisco and San Jose. The second floor of the San Leandro Courthouse collapsed. Reported damage extended from Gilroy and Santa Cruz in the south to Santa Rosa in the north. Surface rupture was reported for approximately 20 miles (32 km), from San Leandro to Warm Springs. Fault rupture may have extended as far north as Berkeley (Yu and Segal, 1996). An area of 888 square miles (2,300 square km) experienced ground shaking of MM VIII or higher (Topozada et al., 1981).
- **April 10, 1881:** This earthquake occurred south of Tracy and possibly near the southern termination of the Greenville fault, based on the interpretation of Topozada et al. (1981) (Figure 8.15-3). In contrast, Wong and Ely (1983) suggested that the 1881 event may have occurred within the CRSBBZ west of Modesto. Minor damage to property was reported from Hollister to Stockton, and chimneys were damaged in the Modesto region (Stover and Coffman, 1993).
- **May 19, 1889:** This earthquake was centered in eastern Contra Costa County (Figure 8.15-3). In Collinsville, a house was toppled over from ground shaking. In Antioch, many chimneys toppled and two small fissures were reported on Main Street. Topozada et al. (1981) estimated the magnitude to be  $M_L$  6.0, while Ellsworth (1990) assigned a  $M$  6.25.
- **April 19 and 21, 1892:** The largest historical earthquakes within or adjacent to the Sacramento Valley are thought to be associated with the CRSBBZ (Figure 8.15-3). These were the 1892 Vacaville-Winters earthquakes on April 10 and 21 ( $M$  6.4 and 6.2, respectively) and a  $M_L$  5.5 aftershock on April 30 (Wong and Ely, 1983; Eaton, 1986; Wong et al., 1988; Unruh and Moores, 1992;

Bakun, 1999; O'Connell et al., 2001). The two largest events in 1892 were felt over a widespread area that extended into Nevada (Dale, 1977). One death, numerous casualties, and extensive damage (including several collapsed buildings) were sustained in the sparsely populated epicentral area. Severe ground effects such as ground cracking and landslides were observed, but it is unclear whether surface faulting accompanied these events. The maximum reported intensities were MM IX for both events.

- **March 31, 1898:** On March 31, 1898, the San Francisco Bay region was shaken by an earthquake that appeared to be centered near Mare Island in San Pablo Bay (Figure 8.15-3). The maximum intensity was MM VIII or greater, and buildings were damaged in areas around the Bay. Topozada et al. (1992) have re-evaluated the magnitude of this event through comparisons with other historical earthquakes, and have assigned a  $M_L$  6.7. This earthquake caused disturbances in the Bay that were reported as a “tidal wave,” suggesting either a seiche or a minor tsunami triggered by deformation of the floor of the Bay.
- **April 18, 1906:** The Great San Francisco earthquake of 1906,  $M$  7.9, centered near Olema, was arguably the most destructive earthquake to have occurred in Northern California in historical times (Figure 8.15-3). The earthquake was felt from southern Oregon to south of Los Angeles, and as far east as central Nevada. It ruptured the northernmost 267 miles (430 km) of the San Andreas fault, from San Juan Bautista to the Mendocino Triple Junction. The average amount of slip on the fault during this earthquake was 16.7 feet (5.1 m) in the area to the north of the Golden Gate, and 8.2 feet (2.5 m) in the Santa Cruz Mountains (WGNCEP, 1996). Damage was widespread in Northern California, and injury and loss of life were particularly severe. Ground shaking and fire caused the deaths of more than 3,000 people and injured approximately 225,000. Damage from shaking was most severe in areas of saturated or loose, young soils. The project site likely experienced ground shaking of MM VI (Topozada et al., 1982).
- **July 1, 1911:** The July 1, 1911  $M_L$  6.6 earthquake probably occurred on the southern Calaveras fault (Figure 8.15-3). This earthquake occurred in a sparsely populated area, and few reports exist from it. The maximum intensity was MM VII. Heaviest damage was reported from Gilroy, Morgan Hill, San Jose, and Santa Clara. Slight damage was reported in San Francisco.
- **April 24, 1984:** The  $M$  6.2 Morgan Hill earthquake caused widespread property damage and injured 27 people (Figure 8.15-3). Most of the loss occurred in Santa Clara County, where 522 private dwellings and 43 commercial buildings were severely damaged. This earthquake caused minor damage to Anderson Lake and Coyote Lake Dams, and triggered a number of landslides along the trace of the Calaveras fault. This earthquake was widely felt over the majority of northern and central California.

- **October 17, 1989:** The M 6.9 Loma Prieta earthquake occurred on or adjacent to the southern Santa Cruz segment of the San Andreas fault (Figure 8.15-3). The cities of Los Gatos, Watsonville, and Santa Cruz were hit with damage, as were San Francisco and Oakland. Shaking was felt throughout the Bay Area and as far away as San Diego and Nevada. While the Loma Prieta earthquake was one of the most expensive natural disasters in U.S. history, causing in excess of \$6 billion damage, the loss of life was significantly less than in 1906. Sixty-two people died and about 3,500 were injured. About 12,000 people were displaced from their homes. As in the 1906 earthquake, the worst damage from shaking occurred to buildings on unconsolidated or saturated soils, or with unreinforced-masonry or poorly designed structures. The project site likely experienced ground shaking of MM VI (Stover and Coffman, 1993).

### 8.15.1.3 Local Geology

The TPP site is currently a vacant agricultural property. The surface slopes gently down at about a 1-percent grade to the northeast. Local drainage is directed towards the northeast. The elevation of the site varies from about 155 to 180 feet. Levees for the Delta-Mendota Canal are present on the south side of the site, and a culvert extending beneath the canal is located on the west side of the site. Overhead electrical lines cross the southeast corner of the site. Three underground pipelines cross the middle of the site, trending southeast to northwest.

The proposed transmission line is located in the foothills of the Diablo Range, part of the Coast Ranges, which represent the prominent, erosion-resistant landforms in the project region. Drainage in the Diablo Range tends to be rapid and intermittent through a few streams.

The region is ultimately underlain by a complex series of sedimentary and volcanic rocks ranging in age from Jurassic to Tertiary. Since their deposition, these rocks have been extensively deformed by repeated episodes of folding and faulting. Valleys within the region are generally filled with unconsolidated sedimentary deposits of Quaternary age. A thick sequence of alluvial fan deposits forms the west side of the Great Valley province in the Tracy area. These sedimentary deposits consist of interbedded sand, gravel, silt, and clay. A detailed description of the structure and stratigraphy beneath the project facilities is presented below.

**Structure.** The overall structure beneath the San Joaquin Valley consists of an asymmetric syncline (Figure 8.15-4). The axis of this fold is approximately parallel to the valley

axis. The western limb of this fold is considerably steeper than the eastern limb, above which the site is located. Within this major fold are many smaller folds and several faults.

**Stratigraphy.** Sources reviewed on the general geology of the area included regional geologic maps compiled by the California Division of Mines and Geology (Wagner et al., 1990) and the U.S. Geological Survey (Dibblee, 1980, 1981). Results from a geotechnical investigation performed on the site area in June 2001 (Hultgren-Tillis Engineers, 2001) were also used. The investigation included drilling four borings to depth of 59 to 79.5 feet, pushing six cone penetration test (CPT) probes to depths ranging from 50 to 100 feet, and performing two percolation tests within the 40-acre site area.

Sedimentary rocks in the locality of the site range in age from late-Mesozoic to Holocene (140 Ma to 10 thousand). The majority of the area is underlain by Quaternary (0–2 Ma) alluvium, which overlies a series of sandstones and shales and represents the filling of a marine basin. This sequence also represents the transition from a marine to a lacustrine and deltaic environment. The sequence was subsequently capped by coalescing alluvial fan deposits. The lithologies of the stratigraphic column at the site, from oldest to youngest, are briefly described below.

The study region is ultimately underlain by the Franciscan Complex, a middle to late-Jurassic (150–165 Ma) assemblage consisting of distinct units of sandstone, shale, chert, greenstone (metamorphosed basalt), and serpentinite (shallow mantle ultramafic). The Franciscan Complex represents a melange, produced by the tectonic fragmenting and mixing of a subduction zone (Norris and Webb, 1990) (Figure 8.15-4). This folded and faulted Mesozoic basement is overlain by a sequence of upper Jurassic to Quaternary sedimentary rocks, commonly called the Great Valley Sequence. This is essentially a thick succession of marine shales with interbedded greywacke. In addition to these marine deposits, the lower part of the Great Valley Group contains basaltic pillow lavas, breccias, and volcanoclastic deposits in some localities. This sequence is generally found at a depth of approximately 21,000 feet (6,400 m) in the San Joaquin Valley (Bloch et al., 1993).

Above the Great Valley Group is the Lower Tertiary Sequence, comprised of siliceous to calcareous shales and sandstones representing deep marine, continental shelf, and possibly deltaic depositional environments (Medwedeff, 1989) (Figure 8.15-4). The transition from marine to terrestrial deposition occurred during the Pliocene (2–5 Ma). Lower Pliocene rocks are shallow marine, while overlying, younger formations tend to be consistent with a brackish-water paleoenvironment. Fluvial and lacustrine siltstones, sandstones, and conglomerates are typical of sedimentary layers deposited during the Pliocene to Pleistocene. Above these units, the recent Quaternary alluvium deposited (Holocene or post-Holocene age). These sediments range from continental alluvial, fluvial, lacustrine, fan-derived sediments to sub-aerial floodplain deposits. Lithologies include sand, gravel, silt, and clay (Wagner et al., 1990). These units outcrop extensively in the TPP–northern San Joaquin Valley region. Bartow (1987, 1991) and Marchand and Allwardt (1981) noted that these geological units may exceed several hundred feet in thickness and consist of poorly consolidated coarse sands and gravels, as well as silts and clay units.

The site is immediately underlain by the Quaternary alluvium deposits (Figure 8.15-5). Recent geotechnical investigations showed that the subsurface at the site consists of a layer of moderately to highly expansive clay underlain by an alluvial sequence of silt, clay, sand, and gravel (Hultgrens-Tillis Engineers, 2001). The surface expansive clay layer varies from about 2 to 7 feet thick. The material is loose to a depth of 1 to 1.5 feet and stiff to hard below this depth. The material directly below the clay consists of 4 to 7 feet of silty sand at four locations, and sandy silt or sandy clay at the other locations. This layer is underlain mainly by sandy silt to silty clay to the depths explored. The clay and silt are typically very stiff to hard and contain varying amounts of sand and gravel. Occasional layers of sand and gravel are present to the depths explored. Two layers of dense sand and gravel were encountered at depths of about 30 and 50 feet below ground surface. The two layers appear to be relatively discontinuous across the site. Two of the CPT probes met refusal in the layer at 50 feet. Groundwater levels were estimated by pore pressure dissipation at three of the CPT locations. Depth to groundwater ranges between 25 to 50 feet below ground (125 to 142 feet above mean sea level), with a local flow direction towards the southeast.

The proposed transmission line crosses alluvial fan deposits from the Quaternary and the Pliocene nonmarine sedimentary rocks (Figure 8.15-5), which consist of conglomerates, sandstone, and siltstone.

**Surficial Soils.** The TPP site is located on agricultural land. Capay clay and Stomar clay loam cover the entire site (see Section 8.9, Agriculture and Soils). The Capay clay soil type occurs in interfan basins and is typically used for irrigated crops or orchards. The Stomar clay loam occurs on alluvial fans and is typically used for irrigated crops or orchards. Both soils are well drained, deep, and have a high shrink-swell potential. Capay clay and Stomar clay loam soil types can be considered prime farmland, if irrigated.

The new transmission line would be located on soils that are generally constituted of clayey loam, with slopes ranging from 0 to 50 percent. Some of these soils are likely to have high shrink-swell potential and severe water erosion hazard.

### 8.15.1.4 Resources of Recreational, Commercial, or Scientific Value

No information was found to indicate that the TPP would adversely affect geologic resources of recreational, commercial, or scientific value. At the TPP site, along the proposed transmission route, the geologic units at the surface and in the subsurface are widespread alluvial deposits that occur throughout the southwestern part of the San Joaquin Valley; these units are not unique in terms of recreational, commercial, or scientific value. The potential for rare mineral or fossil deposits is very low, given the geologic environment in the area. In addition, the TPP site has been previously disturbed by historic agricultural activities and the transmission line route is close to, or within, rights-of-way of other utilities. However, deeper excavation at the plant site and other related facilities could disturb soils that have a high potential for significant paleontological resources to occur (see Section 8.16, Paleontological Resources). However, if a mitigation program is adopted during the construction phase of the project, the direct, indirect, and cumulative adverse environmental impacts on paleontological resources would be reduced to insignificant levels.

### 8.15.2 Geologic Effects and Hazards

No geologic hazards were identified for any part of the proposed TPP that would preclude construction. However, earthquake ground shaking and the presence of expansive soils must be considered in the final design and construction.

#### 8.15.2.1 Surface Fault Rupture

Surface fault rupture occurs when an active fault intercepts and offsets the earth's surface. The State of California delineates zones around active faults under the Alquist-Priolo Earthquake Fault Zoning Act (Hart, 1994) in order to mitigate for the effects of surface faulting. The closest fault zone to the site zoned under the Earthquake Fault Zoning Act is the Greenville fault, at a distance of approximately 9.3 miles (15 km). The project site is located within the CRSBBZ which, as previously been described Section 8.15.1.2, consists principally of blind thrusts and associated back-thrusts. Faults such as the Midway and Black Butte faults may be secondary faults associated with the CRSBBZ. No active (Holocene) or potentially active (late Quaternary) faults have been found to cross the project site or the transmission line during this review (Jennings, 1994). The closest mapped fault to the plant site is the Black Butte fault, located approximately 1.1 miles (1.8 km) to the southwest (Figure 8.15-2). On the U.S. Geological Survey (USGS) map (Dibblee, 1981), the new transmission line route appears to cross the Midway fault; however, the trace is marked as doubtful. There is no conclusive evidence of surface rupture on the Black Butte fault or the Midway fault during the Quaternary (Jennings, 1994); therefore, the surface-rupture hazard from these faults are regarded as low. Based on the above data, the overall surface rupture hazard at the site is considered to be low.

#### 8.15.2.2 Ground Shaking

Strong earthquake ground shaking is probably the most significant seismic hazard that would be expected in the project area. The site has experienced strong ground motions in the past and will likely do so again in the future. The strongest shaking felt at the site was probably due to the 1906 San Francisco and 1989 Loma Prieta earthquakes, where the maximum intensities were MM VI (Stover and Coffman, 1993). Within 62 miles (100 km) of the project site, there are roughly 10 fault zones that are considered to be active (Hart, 1994)

(Figure 8.15-2). An active fault is defined as having had movement along its trace at least once during the past 11,000 years (Hart, 1994).

The 1998 California Building Code (CBC) provides the seismic standard specified by the California Energy Commission (CEC, 1989) for non-nuclear plants such as the TPP. Under the code, the project area is within Seismic Zone 4 and thus would have a Seismic Zone Factor (Z) value of 0.4. (The relevant 1998 CBC section is based on the 1997 Uniform Building Code, Appendix Chapter 16, Division 4.)

To estimate the ground shaking that might occur at the project site in a future earthquake, median estimates of the ground motion parameter—peak ground acceleration—were made using four empirical attenuation relationships and the estimates of the maximum earthquakes listed in Table 8.15-1. The highest peak value, assuming soil conditions at the project site, is expected to occur from a M 6.7 earthquake at a distance of about 0.6 miles (1 km) on the Tracy segment of the CRSBBZ. Such an event would result in a median peak ground acceleration of 0.46 g (46 percent of the acceleration under the force of “g,” or gravity).

In the most recent update of the USGS national hazard maps, which are the basis for the UBC, Frankel et al. (1997) estimated probabilistic ground motions for the U.S. for a 10 percent exceedance probability in 50 years (approximate 500-year return period). From the USGS maps, the 500-year return period peak horizontal acceleration at the site and at the end of the new transmission line are 0.45 g. The ground motions calculated by the USGS assume soft rock soil conditions at the site; however, the project site is situated on soils of alluvial fan deposits that are  $\geq 9.0$  feet (15 m) thick. As a result, ground motions would be modified by the site response of the soil.

### 8.15.2.3 Liquefaction and Lateral Spreading

Soil liquefaction is a phenomenon in which a loose- to medium-dense, saturated granular soil loses internal strength as a result of increased pore water pressure generated by shear strains within the soil mass. This behavior is most commonly induced by strong ground shaking associated with earthquakes. Soil conditions at the site consist predominately of clay and dense

sands, with a relatively deep groundwater level (between 25 and 50 feet). Therefore, the hazard potential for liquefaction is considered low.

For the new transmission line, no specific geotechnical studies exist, so it is not known whether the soils in the region crossed by the transmission line are susceptible to liquefaction. Therefore, site-specific geotechnical investigations may be performed.

### **8.15.2.4 Slope Stability**

The site is on a flat alluvial fan surface. The relatively stable soil and the lack of any significant slopes on or near the site indicate that the hazard from slope instability (landslides and debris flows/lateral spreads) is negligible.

The proposed transmission line route runs through terrain that consists of relatively steep, rolling hills eroded as the result of seasonal flooding. Engineering controls to limit erosion and the potential for landslides would be adopted for the transmission line route.

### **8.15.2.5 Subsidence**

Subsidence can be caused by natural phenomena during tectonic movement, consolidation, hydrocompaction, or rapid sedimentation. Subsidence can also occur from human activities, such as withdrawal of water or hydrocarbons in the subsurface soils. No known subsidence problems exist in the project area.

### **8.15.2.6 Expansive Soils**

The soil profile at the site consists of a surface expansive clay layer underlain by relatively dry soils to depths up to 50 feet. At the plant boring locations, liquid limits and plastic limits results obtained from two soil samples between 0 and 5 feet deep are 50 and 51 percent and 30 and 42 percent, respectively, indicating that the surface clay layer has a moderate to high expansion potential. The underlying materials have lower potential for expansion. Expansive soils change volume with changes in their moisture content. As the moisture content increases, expansive soils swell; as they dry, these soils shrink. Moisture content increases during winter months and/or from heavy irrigation. Moisture content decreases from summer drying and/or

extraction by tree root systems. Structures located directly on expansive soils will heave and settle in response to these movements. Placing a slab over expansive soil will cut down evapotranspiration losses during dry months, tending to retain moisture content beneath the central portion of the slab. The moisture content near the edges of the slab tends to vary with the season and with irrigation practices. Engineering measures will be taken to minimize the impacts of expansive soils at the TPP site.

### **8.15.2.7 Erosion**

The site is on a flat alluvial fan surface. The relatively stable soil and the lack of any significant slopes on or near the site indicate that the hazard from erosion is negligible.

Site topography along the new transmission line suggests that some erosion embankment is occurring during water runoff and seasonal flooding. A hazard from erosion exists, but will be minimized by stabilizing constructed or disturbed surfaces (for example, by compacting soils and grading the surface for better drainage).

### **8.15.3 Mitigation Measures and Cumulative and Indirect Impacts**

Mitigation measures are necessary for the TPP due to potential geologic hazards. The following mitigation measures are proposed:

**Geol-1.** Design the TPP to conform with the California Building Code (CBC) requirements for Seismic Zone 4 and an estimated peak ground acceleration of 0.46 g on soil. A site-specific seismic hazard study may also be required during design.

**Geol-2.** Perform geologic reconnaissance and aerial photograph interpretation along the selected route of the transmission line to determine if any geologic hazards, such as active fault traces, are present.

**Geol-3.** Design the TPP and associated linear facilities to minimize soil expansion, landslide, and erosion impacts.

No cumulative or indirect (growth-inducing) impacts have been identified with regard to geologic resources or hazards.

### 8.15.4 Laws, Ordinances, Regulations, and Standards

The laws, ordinances, regulations, and standards (LORS) that apply to geologic resources and geologic hazards for the TPP are presented in Table 8.15-2. Only LORS for state and local authorities are listed in the table, as no federal LORS apply.

**California Public Resources Code Section 25523(a); California Code of Regulations (CCR) Sections 1752, 1752.5, 2300–2309, and Chapter 2, Subchapter 5, Article 1, Appendix B, Part (i):** These regulations stipulate the environmental review and siting procedures to be followed for the development of power generation projects larger than 50 megawatts. The CEC is the administering agency for this authority.

The TPP will comply with this authority by submitting information on geologic impacts to the CEC and implementing the mitigation measures identified in the final certification.

**California Building Code, 1998.** (The relevant 1998 CBC section is based on the 1987 Uniform Building Code, Appendix Chapter 16, Division 4.) This section of the CBC describes requirements for the design of structures to resist the effects of seismic ground motions.

**International Building Code, 2000.** Section 1615. Earthquake loads–site ground motion. Section 1617.

Proposed conditions of certification are contained in Appendix K. These conditions are proposed in order to ensure compliance with applicable LORS and/or to reduce potentially significant impacts to less-than-significant levels.

**8.15.5      Involved Agencies and Agency Contacts**

<b>Agency</b>	<b>Contact/Title</b>	<b>Telephone</b>
San Joaquin County Building Department City Hall Annex 520 Tracy Boulevard Tracy, CA 95376	Kermit Darrow  Senior Planning Check Engineer	(209) 468 31 79

**8.15.6      Permits Required and Permit Schedule**

No permit requirements that specifically address geologic resources or hazards were identified.

**8.15.7      References**

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**TABLES**

**Table 8.15-1**  
**Median (50th Percentile) Peak Ground Horizontal Accelerations on Soil**

Fault Source	Maximum Magnitude (M)	Type of Faulting <sup>1</sup>	Distances			Peak Ground Horizontal Acceleration (g)				Average
			Horizontal Distance <sup>2</sup> mi (km)	Seismogenic Distance <sup>3</sup> mi (km)	Rupture Distance <sup>4</sup> mi (km)	Abrahamson & Silva (1997)	Sadigh et al. (1997)	Campbell (1997)	Boore et al. (1997)	
CRSBBZ (Tracy)	6.7	R	0.62 (1)	5.58 (9)	4.34 (7)	0.43	0.45	0.46	0.52	0.46
Greenville	7.2	SS	9.3 (15)	9.3 (15)	9.3 (15)	0.24	0.27	0.34	0.26	0.28
Calaveras	7.2	SS	21.7 (35)	21.7 (35)	21.7 (35)	0.13	0.14	0.16	0.14	0.14
Hayward– Rodgers Creek	7.4	SS	27.9 (45)	27.9 (45)	27.9 (45)	0.11	0.12	0.14	0.13	0.13
Concord– Green Valley	6.8	SS	33.48 (54)	33.48 (54)	33.48 (54)	0.07	0.07	0.07	0.08	0.07
San Andreas 1906	7.9	SS	45.88 (74)	45.88 (74)	45.88 (74)	0.10	0.10	0.12	0.12	0.11
San Andreas– Peninsula	7.2	SS	45.88 (74)	45.88 (74)	45.88 (74)	0.07	0.06	0.06	0.08	0.07

<sup>1</sup> R = reverse or thrust fault; SS = strike-slip fault.

<sup>2</sup> Horizontal distance is defined as the shortest distance from the site to the vertical projection of the fault rupture on the earth's surface.

<sup>3</sup> Seismogenic distance is the shortest distance from site to the zone of seismogenic rupture. The top of this zone is assumed to be at a depth of 1.2 miles (2 km) for faults that reach the ground surface.

<sup>4</sup> Rupture distance is the shortest distance from the site to the rupture plane.

Magnitude estimates generally from WGCEP (1999) and WNCEP (1996)

**Table 8.15-2****Laws, Ordinances, Regulations, and Standards for Geologic Resources and Hazards**

<b>Jurisdiction</b>	<b>Authority</b>	<b>Administering Agency</b>	<b>Compliance</b>
Federal	None applicable	—	—
State	California Public Resources Code § 25523(a); CCR §§ 1752, 1752.5, 2300–2309, and Chapter 2, Subchapter 5, Article 1, Appendix B, Part (i)	California Energy Commission	Compliance with this regulation is discussed in 8.15.2
Local	California Building Code (CBC), 1998. Based on Uniform Building Code, 1997, Appendix Chapter 16, Division 4.	San Joaquin County– Building Department	Compliance with this code is discussed in 8.15.2

CCR

= California Code of Regulations

**FIGURES**

**Figure 8.15-1.**

**Physiographic Provinces, Coast Ranges-Sierran Block Boundary Zone, and Major Faults  
in Northern and Central California**

**Figure 8.15-2.**  
**Quaternary Faults Within 100 km of the Project Site**

**Figure 8.15-3.**  
**Quaternary Faults and Historical Seismicity, 1808-2001, Within 100 km of Project Site**

**Figure 8.15.4.**  
**Cross Section Through the Coast Ranges and San Joaquin Valley**

**Figure 8.15-5.**

**Geologic Map of the Project Area**